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THE ACQUISITION OF CONCEPTS OF CONSERVATION

by

GUY R. LEFRANÇOIS

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ABSTRACT

This study is concerned in general with the sub-ordinate capabilities necessary for successful performance of conservation tasks, and with the role of verbalization in the development of the notion of invariance. The experimental work is limited to the conservation of mass. Two hypotheses are examined: (1) Through a training program based on an analysis of the sub-ordinate capabilities involved, the development of conservation can be accelerated in young children; (2) If the child is asked to verbalize his performance of subtasks, he will be more likely to succeed.

A sample of 60 five and six year-old children who did not give any correct responses on a conservation of mass pretest was drawn from two Edmonton elementary schools and one kindergarten. Subjects were randomly assigned to one of three experimental conditions: verbalizing, non-verbalizing, and no-training. Training, for the first two groups, consisted of individual sessions with the experimenter where the subject was presented with a series of tasks ordered from simplest to most difficult. These tasks were intended to lead logically to the operations which Piaget has labelled Identity and Combinativity--operations which are manifested in correct conservation responses. In addition, the verbalizing group subjects were asked to verbalize reasons for their responses to the

training tasks. Subjects in the third group did not participate in any training session but were administered all relevant tests.

Results of the experiment, as reflected in posttests and retention tests, indicated that: (a) treatment group subjects outperformed the no-training group; (b) more verbalizing group subjects than non-verbalizing group subjects acquired conservation, and (c) there was a significant amount of transfer from success on conservation of mass tasks to conservation of number tasks.

It was concluded that the concept of conservation of mass can be developed in young children prior to that time when they would have acquired the concept naturally, and that verbalization is a significant factor in the acquisition of conservation.

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CHAPTER I

INTRODUCTION

General Problem, Delimitation and Overview

"Are they still the same, or does this one have more or less?"

This, the criterion question in the classical Piaget and Inhelder conservation tests (1941), referred to the quantitative attributes of objects. Included among test materials were balls of plasticine, rows of counters, and beakers of water or of beads. The child's responses determined whether he had acquired the concept of conservation in a specific area--that is, whether he realized that invariance is maintained despite deformations or spatial displacements of objects or groups of objects. From these experiments there evolved a large body of observational data and theoretical interpretations of these data. Children were believed to acquire conservation in separate areas at different ages. Repeated observations led to the development of an ordinal scale placing the conservation of mass at the earliest level and that of volume several years later. Replications of the 1941 experiments have tended to confirm both the age levels and the ordinal sequence of attainment.

The theoretical implications of these findings were then largely limited to a descriptive explanation of the development of the child's representations of his world--a speculative inventory of the ontogenetic growth of the mind. More recently, attempts have been made to

extrapolate these findings in the area of natural growth to that of artificial or laboratory-induced development. If a combination of haphazard experiences in the child's normal environment leads to the development of conservation, then a systematic attempt to provide the child with directly pertinent analogous experiences in a classroom or in a laboratory should lead to a more rapid development of conservation. Early attempts to test this prediction were seldom successful; however, largely because of the experimental and theoretical inadequacies discovered in retrospect, success has tentatively been obtained (notably by Smedslund (1961e, 1961f) and Wallach and Sprott (1964)).

Further work in this area is of direct theoretical and practical import--of theoretical import in that acquisition studies can be geared specifically toward refuting or supporting explanatory models of child thought and development; of practical import in that logical extrapolation of accelerated acquisition of concepts at an early level would predict that various types of concepts and capabilities can be developed at other age levels. The unknown conditions and limitations of this acquisition could well lead to much research that would be of significance to child and developmental psychology.

This study is concerned in general with the subordinate capabilities necessary for successful performance of conservation tasks, and with the role of verbalization in the development of the notion of invariance. The experimental work is limited to the conservation of mass, not because similar work could not be attempted in all

other areas of conservation, but because a test of the theoretical postulates advanced requires experimentation in one area only.

The second chapter defines conservation, summarizes relevant early experiments, and reviews recent studies that are directly related to the present research. In the third chapter, these studies and several others are examined in the light of three specific theoretical postulates from which are derived the hypotheses tested in the present work. An outline of the procedure and of the experimental design comprises the fourth chapter. The fifth is concerned with the analysis of data, the sixth with the validation of the treatment hierarchy, while the seventh deals with conclusions and implications.

CHAPTER II

REVIEW OF RELATED RESEARCH

Introduction

Essentially this study investigates the problem of whether or not the development of concepts of conservation can be significantly accelerated through instruction. Although few studies have attempted to deal directly with this problem, considerable research is relevant to the theoretical and procedural problems involved. This second chapter examines those studies which are directly relevant to the problem itself. Some research related to theory and procedure is also mentioned here but is reviewed more thoroughly in the third chapter.

Definition and Classical Conservation Experiment

In this context the term conservation refers to the realization that quantity or amount remains invariant when nothing has been added or taken away from an object or a collection of objects despite changes in form or spatial displacement.

The specific type of conservation pertinent to this study, and the classical Piaget and Inhelder experiment (Piaget and Inhelder, 1941) associated with it are described below.

Conservation of substance (also referred to as mass or continuous solid). This refers specifically to the conservation of solid matter.

The traditional experiment presents a subject with two identical plasticine balls. The subject is told that they contain the same amount of plasticine. One of the balls is then flattened or otherwise deformed. The subject is then asked whether the objects still have the same amount of plasticine in them, or more, or less.

From Non-Conservation to Conservation

Attention was first drawn to the phenomena of transition from non-conservation to conservation, in the domains of substance, weight and volume, by Piaget and Inhelder (1941). They reported that conservation of substance, weight, and volume were reached on the average around the ages of 7-8, 9-10, and 11-12 respectively. Some ambiguity surrounds the intended meaning of "on the average" as Piaget and Inhelder did not specify whether this indicated that 7-8 year old subjects had reached conservation when they answered all conservation items or when they answered a certain proportion of items. In replicating these experiments, Vinh-Bang (1959) used a 50% level whereas Elkind (1961) used a 75% criterion. Elkind justified his use of this level on the grounds that Piaget had elsewhere used a 75% criterion in assigning tests to age levels (Piaget, 1951). Both Vinh-Bang and Elkind confirmed the generality of the developmental sequence, but found slight differences in the ages at which the different types of conservation appeared. Vinh-Bang found conservation of substance at age 7½ whereas Elkind's subjects did not reach criterion performance

until age nine. The corresponding levels for conservation of weight were age 8 for Vinh-Bang and age 10 for Elkind. Lovell (1960) in England found results that closely paralleled Vinh-Bang's.

It is to be noted that the discrepancies between ages for the attainment of conservation as found by Elkind and Vinh-Bang are even more startling if a 50% criterion is applied to the Elkind data. The age levels for conservation of both mass and weight are then 6, with the six-year-old subjects answering correctly 51% of the conservation of mass items and 52% of the conservation of weight items (Elkind, 1961). Elkind's subjects do not, when using this criterion level, exhibit the clear developmental sequence described by Piaget and later confirmed by Inhelder (1944). While Elkind does not interpret his data using a 50% criterion, he does draw attention to the slight differences between his results, using a 75% level, and Piaget's. These he explains on the basis of his small samples. It is interesting to note that Elkind had 25 subjects at each of seven age levels. Piaget and Inhelder had a total of 180 subjects, also at seven age levels (Piaget and Inhelder, 1941)--only 5 more. On the other hand, Vinh-Bang, whose results closely parallel Piaget's, had a sample of 1500 Geneva children aged 4 to 12.

In summary, both Elkind and Vinh-Bang see their results as confirming Piaget's although they used different criterion levels to determine at what age conservation is achieved. Piaget did not specify his criterion level. Given that all three investigators used identical

procedures, then one must conclude, if their results are reliable, that the appearance of concepts of conservation falls within a rather wide age-range, and that there is no fixed developmental sequence for conservation of mass and weight; or that one or more of the samples were atypical in terms of some factor related to conservation. It would appear that the latter may be the case in view of the fact that Smedslund (1959) has found earlier transition ages in a group of children from a superior socio-economic milieu in Geneva.

A Theoretical Explanation for the Acquisition of Conservation

> ...little is known thus far about the specific ways in which the transition from lack of conservation to the presence of conservation takes place (Wohlwill and Lowe, 1962).

Not surprisingly, perhaps what has been the most systematic, if preliminary and tentative, attempt to explain the acquisition of conservation was undertaken by Piaget. The essential aspects of his theorizing are summarized and reviewed in this section.

Piaget asserts that the evolution of conservation is a function of an internal process, equilibration of cognitive actions--a process which results in the manifestation of operational reversibility and identity, both of which are fundamental to conservation (Piaget and Inhelder, 1941).

The developmental process which culminates in the acquisition of conservation of mass, through equilibration, comprises four major

steps (Piaget, 1957). In step 1, the subject attends to only one of either dimensions (length or width) but not to both. In step 2, after a series of repeated centrations on one property, the subject comes to substitute for it a series of centrations on the other property. Step 2 may include a sequence of alternations between the two properties, but is characterized by a continuing inability to consider both at once. Step 3 includes a somewhat heterogeneous set of behaviors which is neither clearly conservation nor clearly non-conservation. The subject can now apprehend both properties within a single cognitive act, but the result is typically a noticeable hesitation and conflict. The fourth step is simply an extension of the third, leading directly to the necessary conservation of quantity.

While the foregoing constitutes a description of the developmental sequence for conservation, it is not an explanation of it. Piaget proposes an explanatory model which is essentially probabilistic. Step 1, centration by the subject on one dimension alone, is more probable than step 3, apprehension of both dimensions in a single cognitive act, for essentially the same reason that the probability of either of two coins turning up heads on one toss is greater than the probability of both turning up heads. Transition to step 2, centering on the other property, is thought to become increasingly probable as the subject's dissatisfaction with his responses in the face of changing perceptual conditions increases. Having once noticed both dimensions successively, the subject is likely to alternate between them as

perceptual conditions change. This alternation increases the probability that both dimensions will be considered together. In order to achieve conservation of mass, the subject need only discover that the dimensions covary in compensatory fashion.

One of the intriguing assumptions implicit in this theoretical explanation is that children are exposed, in the course of their early development, to objects which exhibit transformations of the kinds demonstrated in the conservation experiments themselves. In fact, Piaget's model is directly related to the development of conservation in the conservation-problem experiment--an experiment which is designed not to develop conservation, but to ascertain whether or not the subject has already acquired it. This consideration gives rise to two questions, the answers to which may or may not be related:

1) What theoretical model will best explain the acquisition of conservation in the laboratory under conditions where the probability of developing conservation is highest?

2) What theoretical model will best explain its natural development?

This study is concerned with the first question and with a third related to the first. Under what conditions will the probability of developing conservation be the highest? Attempts that have been made to answer these questions are reviewed in the following section.

Relevant Experimental Work

This section is meant to include reported research which is directly relevant to the major hypothesis under consideration in this

study. In general terms this hypothesis maintains that the discovery of conservation of quantity by young children can be accelerated through appropriate instruction. A more specific, theory-derived formulation is given in the next chapter. In the present section an attempt is made to evaluate pertinent studies in terms of their support or contradiction of the hypothesis, in terms of the reliability and generality of their findings, and in terms of their contributions to the clarification of existing theoretical models, or their introduction of new models, which might serve to explain at least part of what is known about the acquisition of concepts of conservation.

Research on the conservation of number and weight, where this research is of direct theoretical and/or procedural relevance to the present study, is included despite the fact that the experimental aspect of this study is limited to the conservation of mass.

Conservation of number. The first two studies considered here, those of Churchill and Harker, are reported by Flavell (1963, p. 371). Churchill, in the course of eight one-hour play sessions designed to give practice in grouping, seriating, matching and ordering various objects, succeeded in bringing about significant differences between control and experimental groups on conservation of number posttests. Harker did a similar experiment but with a briefer training program. Her experimental groups did not show clear-cut gains. Flavell, in reviewing these studies, stated that both the training procedure and the behavior it was to affect were too global and heterogeneous to

permit any definite conclusions as to precisely what experiences influenced specific numerical skills.

A less global and better controlled study is that of Wohlwill and Lowe (1962). Three types of training, all directed specifically towards the acquisition of number conservation, and directly related to three distinct hypotheses, were given to separate groups of 18 subjects with a control group receiving no training. The first hypothesis, referred to as the reinforcement hypothesis, maintained that as the child gains experience in counting numerical collections in different spatial arrangements, he comes to learn that number is invariant. Therefore, systematic practice in counting rows of objects before and after rearrangement should promote conservation. Reinforcement involved giving the subject a 'chip' whenever he enumerated correctly. The inference hypothesis, on the other hand, says essentially that the child will infer conservation when he realizes that invariance is maintained when nothing has been added to or taken away from the set. Related training involved reinforced practice in counting rows of objects before and after change in length, as for the first group, plus experience in seeing that addition and subtraction of elements did affect the numerical value of the set. A third prediction, the differentiation hypothesis, holds that the child must learn to discriminate between relevant and irrelevant aspects of the stimulus situation before he can discover conservation. Training for the third group consisted of an attempt to dissociate numerical value from the

configuration of the collection by varying the length of single sets without adding or removing elements from them. Results for all three training programs were negative.

There are several relatively serious weaknesses in this study. In the first place, it is shown in the next chapter that these three hypotheses could well have been included in a single theoretical model giving rise to one training procedure involving combinations of the three separate training programs used by Wohlwill and Lowe. At the same time, justification is given for the notion that no single training method as used by the authors is likely to prove effective in developing conservation. In the second place, what may well prove to be the most crucial single factor in any acquisition experiment with young subjects, verbalization, has not been controlled or utilized in this research. Finally, the verbal conservation pre- and posttests made use of what the authors admit is a suggestive question: "Who has more chips, you or I?" (Wohlwill and Lowe, 1962, p. 156) They attempt to justify the use of this question on two counts. First, the question is initially posed where the chips are arranged in two parallel rows, equal in number and in length. Hence the perceptual array militates against the suggestiveness of the question--and the subjects do in fact resist the question by maintaining that the rows are equivalent. Furthermore, the same question is used in both the pre- and posttest and should therefore constitute a constant, if biased, effect.

Obviously, despite the fact that the suggestiveness of the question appears to have no influence when the rows are of equal length, there is no guarantee that the same held true when one of the rows was rearranged. In other words, where subjects gave non-conservation responses in the posttest, there is no way of knowing whether they did so because they had not acquired conservation or because they were affected by the suggestiveness of the question. The nature of the 'constant effect' is, in fact, directly opposed to the hypotheses being tested.

Accordingly, it is not surprising to find that the results of the study were largely negative. The group as a whole did show significant improvement from pre- to posttest on a nonverbal measure of conservation, which could indicate that some sort of empirical rule had been learned by the experimental group. On the other hand, there was virtually no training effect in any subgroup as measured by the verbal test--nor were there any significant differences between any subgroup and the control group on either of the tests.

The one successful attempt to induce number conservation in children which is based on the Piagetian notion of reversibility, is that which was undertaken by Wallach and Sprott (1964). The training procedure employed was a simple one. Subjects were presented with corresponding rows of beds and dolls. These were subjected to a maximum of eight displacements (dolls moved closer together, beds further apart and vice versa) with the addition or subtraction of an

element in one of the rows after alternate displacements. Subjects were asked to predict whether the dolls would fit in the beds after each displacement. They then tested their predictions by placing the dolls in the beds. The hypothesis being examined was this (Wallach and Sprott, 1964):

> A property will be regarded as conserved under an operation which removes a defining attribute of that property, if the inverse operation is expected to lead to the attribute's reappearance at the same value. (p. 1067)

Essentially, what this says is that when the child has acquired true reversibility (see Chapter VI, or Piaget and Inhelder, 1941, p. 17), he will have acquired conservation. Since the results of the experiment were as expected (14 out of 15 subjects acquired conservation) the authors conclude that the hypothesis is supported, and consequently, that reversibility is the crucial operation involved in conservation.

In the absence of evidence to the contrary, the writer is inclined to agree with this interpretation--an interpretation which is also Piaget's. However, there are several alternative explanations for the results of this experiment. In the first place, where the training program deals with problems that are, in effect, conservation problems, and where the correct responses for these problems are given to the student after each training trial, it is reasonable to suppose that even in the absence of reversibility, the subject would eventually, through reinforced repetition, come to give the right answer. That is, he would be expected to learn that there is a fit between these

corresponding rows of objects unless an element is added or removed from one of the sets. Whether or not operational reversibility is involved in his subsequently correct responses to conservation of number test items cannot be readily determined. Nor can the treatment used here be generalized to conservation of amount, as the authors argue (1964, p. 1057), where there is no accurate way of verifying a prediction--where there is, in fact, no readily observable 'fit' between a transformed object and its unchanged counterpart.

In the second place, the mean age of subjects in the experimental group was 7-0; almost half of the total group tested by the authors had already acquired conservation (28 conservers, 30 non-conservers: Wallach and Sprott, 1964,p. 1063). The result of the present study, as well as the work of Piaget and Inhelder (1941) would lead to the expectation that those subjects who did not give conservation responses on the pretest would be on the verge of conservation--hence probably very little would be needed to develop conservation in them. The Wohlwill and Lowe study (1962), reported earlier, employed what is, in effect, the same treatment (reinforcement hypothesis), but with younger subjects (ages 4 to 5), and was unsuccessful in developing conservation.

Conservation of substance and weight. Most of the work in this area which is directly pertinent to this study has been done by Jan Smedslund of the University of Oslo. Reports were published by him in the Scandinavian Journal of Psychology in a series of six articles

(1961a, 1961b, 1961c, 1961d, 1961e, 1961f).

The first article in the series (1961a) comprises a systematic review of theory and experimentation relevant generally to the development of Piaget concepts and specifically to the development of concepts of conservation of substance (mass) and weight. Reference is made to this article, wherever appropriate, in the course of this and of the next chapter.

The second article (1961b) reports an experiment which consisted of an attempt to facilitate the conservation of weight through exercising a related schema, the addition-subtraction one, in one group of 16 subjects, and by giving 32 reinforced trials on conservation of weight itself to the second group. A third group, also of 16 subjects, served as a no-training control. Training for the first group consisted of trials where pieces of plasticine were added to or subtracted from a larger plasticine ball before and after it was compared by the subject to a standard on a scale balance. The second group was given practice in predicting whether two balls of equal weight would still be equal after one of the balls had been deformed. Subjects then tested their predictions on the scale balance. Comparison of posttest results revealed that the outcomes were essentially negative. While there was some pre- to posttest improvement, none of the between-group differences were statistically significant.

The next experiment (1961c) involved an attempt to extinguish conservation responses through withdrawal of reinforcement (more

precisely, by inducing non-conservation responses through deception). Experimental groups comprised thirteen 5-7 year-old children who showed complete conservation of weight on a pretest, and 11 children who had no conservation responses on a pretest but showed complete conservation on a second test after two sessions of reinforced practice in conservation. Training for both groups consisted of the experimenter deforming one of two objects of equal weight and surreptitiously stealing a small piece from the deformed object. Subjects then predicted whether the objects would still weigh the same. These were then placed on the scale balance and the inequality observed. Finally, the subjects were asked to explain why the unchanged object weighed more.

This experiment was meant to compare two theories which give rise to contradictory predictions regarding its final outcome. The first, referred to as 'learning theory', postulates essentially that a child acquires concepts of conservation "as a function of repeated external reinforcements." (1961a, p. 13) It would predict that the conservation of weight concept can always be extinguished regardless of whether it has been established in the laboratory or in normal life (1961c, p. 85). Piaget's theory, on the other hand, asserts that conservation develops as a function of equilibration, a process which is heavily dependent on activity and experience. Practice is assumed not to act through external reinforcement but by a process of mutual interaction and co-ordination of the subject's own activities. Equilibration

theory would predict that genuine concepts of conservation should be impervious to extinction.

Results of the experiment gave some support to equilibration theory but none to reinforcement theory. Not one of the subjects who had acquired the concept through reinforced practice showed any resistance to extinction. On the other hand, six of the thirteen subjects who had achieved conservation of weight normally did resist. They generally argued that a piece of plasticine must be missing, that it must have fallen on the floor, or that the experimenter had removed it.

The fourth article in the series (1961d) reports an attempt to develop conservation of weight by dissociating irrelevant from relevant cues in a series of thirty-six training trials. Eleven subjects who gave no conservation responses on a pretest participated in the experiment. The objects to be compared were usually of unequal size and weight, with a random arrangement of size to weight relationship. That is, the larger object was sometimes heavier and sometimes lighter. Objects were placed on the scale before the child was asked to say which was heavier as well as which was larger. Results on both a conservation of weight and a conservation of substance posttest did not give evidence of any gains.

The next article (1961e) approaches the problem of the acquisition of conservation from a different theoretical model. Smedslund had

observed in a previous study (1959) that some subjects seemed to discover conservation when the problem situation involved both deformation and addition/subtraction. He explains this on the basis that some sort of cognitive conflict is engendered where the subject has to combine his impression that change in shape of one object results in one type of inequality while addition or subtraction of material from the other object results in a reversal of inequality. This explanation led to the hypothesis that the normal origin of the concept of conservation of substance resides in the cognitive conflict occasioned when two related but conflicting schemata are activated at the same time - a hypothesis which is essentially identical to the third step in Piaget's model (see p. 8). The experiment designed to test this hypothesis employed a training procedure where subjects were exposed to two identical plasticine objects, one of which was later deformed while the other had plasticine added to or taken away from it. Thirteen subjects who had no previous conservation responses took part in the experiment. No control group was used. Five of the thirteen subjects responded in accordance with the addition/subtraction schema. The other eight did not. Of the first five, four gave a number of conservation responses in the posttest, complete with logical rationale. None of the remaining eight did likewise. Smedslund interprets these results as tentative support for his cognitive-conflict hypothesis.

The final experiment (1961f), which is largely a replication of the foregoing, but with a control group added, tends to add further support to the hypothesis. It is the first in the series in which the experimental group outperformed the control group.

This concludes the review of research which is most directly pertinent to the problem at hand. Several additional studies, mainly non-European in origin, are reviewed in the following chapter where a more careful interpretation of the theoretical import of the Smedslund studies is also undertaken.

CHAPTER III

THEORETICAL POSTULATES AND HYPOTHESES

Introduction

Thus far, several theoretical positions relating to the acquisition of concepts of conservation have been mentioned. These have included the equilibration theory from a probabilistic point of view (Piaget, 1957), a cognitive-conflict position (Smedslund, 1961e, 1961f), and a reinforcement approach (Smedslund, 1961a, 1961c). Research reported and available to date has not granted unequivocal support to any of these three positions. Piaget's theoretical explanation is only tentatively supported; the reinforcement approach has not been confirmed in the Smedslund or the Wohlwill and Lowe studies, and the cognitive-conflict position has received only tentative support in the fifth and sixth Smedslund experiments. Two other hypotheses tested by Wohlwill and Lowe (1962), the inference and the differentiation hypotheses (essentially identical to the Smedslund addition/subtraction-schema experiment and the extinction of perceptual cues experiment), have not proven fruitful. Admittedly, there is not a sufficient amount of clear and reliable evidence to warrant the unqualified acceptance or rejection of one specific theoretical position, although very tentative support has been obtained for the cognitive conflict position.

The remaining pages of this chapter are devoted to the

development of postulates, and to the derivation of hypotheses from these postulates, relative to the acquisition of conservation.

Theoretical Model

A parsimonious statement of the model which, in this study, is evaluated specifically in relation to the development of concepts of conservation of mass, is given below. Justification and explanation of the model follows.

Postulates:

1. The development of Piagetian concepts is to a considerable degree independent of age level, but is related to mental capability and to experiential factors.

2. The performance of a high-level task implies the ability to perform a set of related sub-ordinate tasks.

3. Transition from sub-ordinate capabilities to the final task may be brought about by verbalization which would effect a cognitive re-organization of these capabilities in accordance with the needs imposed on the individual by the task.

Hypotheses:

If the postulates are valid, then

1. Through a training program based on a careful analysis of the subordinate capabilities involved, conservation can be made to appear in subjects prior to that time when they would have acquired the concept naturally.

2. If the child is asked to verbalize his performance of subtasks, he will be more likely to succeed.

Justification and Explanation of the Postulates
with Respect to Conservation

1. The development of Piagetian concepts is to a considerable degree independent of age level, but is related to mental capability and to experiential factors.

Despite what might appear to be an implicit denial of this postulate in the work of Piaget and Inhelder, there is ample evidence that it is valid. These investigators did report discovering conservation at a specific age level (1941) and the findings were replicated later (Inhelder, 1944; Vinh-Bang (in preparation)). These age levels, however, were only averages. Smedslund (1959), on the other hand, found earlier transition ages for a group of children from a higher socio-economic milieu in Geneva. Feigenbaum (1963) also found conservation at different age levels. Even though specific developmental phenomena generally appear in close proximity to specified ages, this should not be taken to indicate that other causal factors are not involved.

That there is a relationship between the advent of conservation and mental capability as reflected in mental age may be supported by the Smedslund study mentioned above, if, in fact, those children from higher socio-economic milieus have higher average mental ages than the Piaget or the Vinh-Bang samples. In addition, direct evidence of the relationship of mental age to the acquisition of conservation was found by Feigenbaum (1963).

The relationship of experience to the development of conservation

has never been seriously questioned. It was assumed by Piaget that activity and experience play a crucial role in the development of concepts. The inability of experimenters, in early studies, to affect the acquisition of these concepts appreciably may be explained largely in terms of the inadequacy of the training programs they used. The recent successes of Smedslund and Wallach and Sprott, although only tentative, would indicate that conservation can be developed by providing children with appropriate experiences. In addition the argument that experiences influence the development of concepts has been used by Dodwell as an explanation for the apparent lack of rigidity and neatness in the developmental patterns of many children (Dodwell,1960; 1961).

2. The performance of a high-level task implies the ability to perform a set of related sub-ordinate tasks.

The intuitive validity of this postulate can readily be appreciated. At a very simple level, the child cannot write before he can hold a pencil or before he can move it in accordance with the prescribed form of written symbols. Gagné (1962), whose theory deals largely with hierarchical arrangements of subordinate capabilities, has confirmed the hypothesis that the individual must be able to perform all the subordinate tasks in order to perform a higher one. Further reference to his theory is made later. The usefulness of this postulate resides largely in its contribution towards the development of appropriate training programs for teaching various concepts and capabilities. This will become more evidence in the chapter on procedure which follows this chapter.

3. Transition from sub-ordinate capabilities to the final task may be brought about by verbalization which would effect a cognitive re-organization of these capabilities in accordance with the needs imposed on the individual by the task.

This postulate is very similar to Gagné's contention that "attaining each new learning set depends upon a process of positive transfer which is dependent upon recall of relevant sub-ordinate learning sets and upon the effects of instructions." (1962, p. 358) Since one of the functions of instructions is to identify required terminal performance, insofar as the phrases "needs imposed by a task on an individual" and "required terminal performance" are identical, then the last portion of this postulate is valid to the extent that Gagné's contention is true.

Precisely how cognitive re-organization takes place is a matter of speculation. To say, as has Smedslund (1961e), that cognitive conflict is the crucial factor in re-organization of schemas, is to postulate a factor which can account for learning only where a problem situation brings into play two contradictory sets of behaviors. Conservation problems evidently can do this. A deformed plasticine ball may appear to be both larger (longer) and smaller (thinner). On the other hand, a problem in division may simply require the recall and re-organization of the multiplication, addition, and subtraction schemas--schemas which are not in conflict in this situation.

For purposes of this study, it is adequate to postulate that some sort of transfer between sub-ordinate capabilities must take place

if the learner is to succeed in the final task. Whether or not cognitive conflict is involved in the transfer is a matter which will be determined by the nature of the tasks presented, or by the subject's reaction to the problem.

That verbalization (internal or external speech describing the child's specific performance and/or the principle of solution) may be a significant factor in transfer and cognitive re-organization is supported by research. Other than the direct experimental evidence presented by Kuenne (1946) and Bruner (1964), there are the theoretical explanations and experimental conclusions of the Russian psychologists, Luria (1959; 1961), Vygotsky (1962), and Sokolov (1959), who see language or the 'second signal system' (Luria, 1961) as a basic factor in psychic organization. Their contentions are well expressed by Sokolov (1959):

> ...speech emerges not only as the means of expression of thoughts, but primarily as the means of their formation, the means of analysis and synthesis, abstraction and generalization of material reality; and the material of logic operations is constituted by all of these sense (felt and perceived) data of material reality. (p. 669)

This is not unlike Bruner's (1964) recently advanced assertion that it is not until the child can represent reality symbolically that he is capable of productive as well as reproductive thinking (1964, p. 5). Evidence that this is the case is provided by a transposition experiment undertaken by Kuenne (1946). Seventy-three per cent of the subjects who verbalized spontaneously or in response to questioning

transposed whereas none of the subjects who had not verbalized the principle of solution succeeded. The experiment involved training the groups to select the smaller of a pair of squares. The subjects were then tested in counterbalanced order with smaller squares.

An indication as to the nature of the verbalization related to successful performance on conservation tasks is found in a study by Nair (1963). The experiment in question dealt with conservation of continuous fluid (water) in rectangular tanks of unequal dimensions. Two-thirds of the subjects who responded correctly used non-perceptual arguments to justify their responses. Only 15% of those who answered incorrectly resorted to non-perceptual arguments. The non-perceptual arguments had to do with action in the sense that a duck, floating on the water, was said to have taken all the same water with it as the water was poured from one container to the other. Bruner concludes as follows (1964):

> It is plain that if a child is to succeed in the conservation task, he must have some internalized verbal formula that shields him from the overpowering appearance of the visual displays...(p. 7)

It would appear, then, that verbalization of the perceptual features alone does not help in conservation tasks. It is likely that this would, in fact, direct attention to the misleading aspects of the test situation. Another experiment by Bruner and Kenney (in press) reported by Bruner (1964) indicated that in a problem involving re-building a matrix with one element transposed, those children who used

confounded descriptions of matrix elements were twice as likely to fail as those using dimensional or global descriptions. The elements in the matrix were nine cylinders of different widths and heights. A dimensional description would be, "This one is higher, that one shorter"; a global description, "that one is bigger and that one smaller", and a confounded description would involve both dimensional and global terms: "that one is taller and that one is little." Results here do not contradict those of the Nair experiment despite the fact that in the former dimensional (perceptual) description is positively related to success while in the latter perceptual arguments were negatively related to success. In the Nair experiment, perceptual features of the test situation are a source of error, while in the Bruner and Kenney experiment, awareness of perceptual features is essential for responding correctly.

In conclusion, although verbalization has seldom been controlled or utilized in learning experiments, its inclusion in this postulate is supported both by theory and by research evidence.

An Empirical Test of Theory

The following chapter describes an experimental procedure consistent with the theoretical postulates developed in the present chapter. This procedure is designed to test the hypotheses derived from these postulates. A test of the hypotheses constitutes, in effect, a test of the postulates themselves, as is shown in the next chapter.

CHAPTER IV

PROCEDURE

Introduction

In order to be consistent with the three postulates developed in the third chapter, and in order to provide data which would be a direct test of the hypotheses derived from these postulates, a treatment was devised in close accordance with the following theoretical considerations:

1. The first postulate would be supported or refuted directly on the basis of the results of an attempt to accelerate the acquisition of conservation. That is, if such an attempt were successful, it would have been demonstrated that the development of this concept was, to some degree, independent of age level, but dependent on experiential factors, and very probably related to mental capability. It should be noted, however, that insofar as mental age reflects both chronological age and experience as well as socio-economic level, its relationship to the development of conservation will be confounded by the interrelatedness of these factors.

2. The second postulate would also be supported or refuted by the success of an attempt to develop conservation in subjects provided the experimental procedure was based on an analysis of capabilities sub-ordinate to the criterion conservation tasks. It can readily be argued that where investigators have been successful in developing

conservation in their subjects, those subjects who were successful did in fact possess the relevant sub-ordinate capabilities. By the same token, lack of success can logically be attributed to the lack of some capability in a subject. Whether or not that capability could have been developed can only be partially determined by the success of the present research.

3. The validity of the third postulate would be determined by the veridicality of the second hypothesis. That is, if subjects who were made to verbalize their performance of sub-ordinate tasks were more successful than those who did not verbalize, it could be inferred that verbalization had been instrumental in the cognitive-re-organization of capabilities necessary for successful performance.

The experimental design adopted to test the hypotheses made use of three experimental groups, two of which were exposed to treatments identical in all but one respect. One group was asked to verbalize (group V) while the other was not (group NV). The third group served as a no-training control (NT). The treatment proper was based on a hierarchical classification of sub-ordinate capabilities related to the conservation of mass. The task hierarchy for conservation of substance is diagrammed in Figure 1. A related treatment is detailed in the following section. The development and validation of the hierarchy is discussed in Chapter VI.

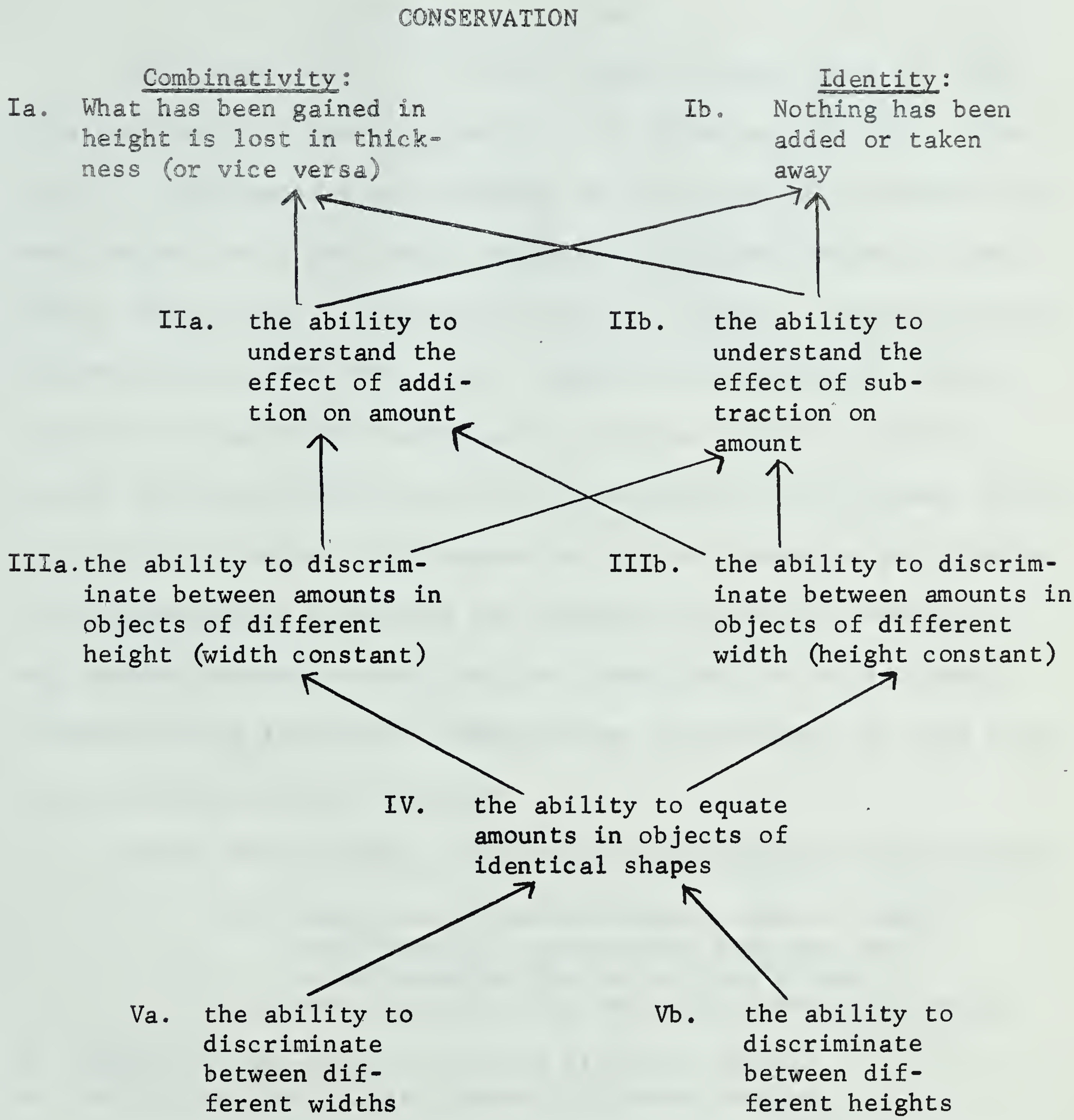

Figure 1

Conservation of Substance: Hierarchy of Sub-ordinate Capabilities

Experimental Treatment

The treatment for all subjects began at level Va of the hierarchy and proceeded upward through Vb, IV, IIIa, and on to the final task, Ib. Instructions and questions at each level were repeated for every subject until the correct responses were given or until a maximum of three separate repetitions had been reached. The experimenter then proceeded to the next level. Regardless of success or lack of success, the session was continued to the final level in order to provide data that could be used in the validation of the linear arrangement of the hierarchy. Mild praise for correct responses was provided by the experimenter throughout the training session (no comments of this nature were made during the test themselves, or for incorrect responses during training). Materials and instructions for each level of the hierarchy are as follows:

(Note: The following symbols were used throughout this section:

Qi--Questions by the experimenter where i stands for a specific question for both the non-verbalizing and the verbalizing groups
V--Added questions for the verbalizing group only).

Va Ability to discriminate between different widths
Vb Ability to discriminate between different lengths

Material: Two cylindrical wooden objects of different length but equal width (set A, 1X6 inches, and 1X4 inches), and two of equal length but of different width (set B, 1X5 inches, and ½X5 inches).

Va Q1 (Indicating A) Which is wider and which is narrower?

V--How can you tell that this one is wider? narrower?

Vb Q2 (Indicating B) Which is longer and which is shorter?

V--How can you tell that this one is shorter? longer?

IV The ability to equate amounts in objects of identical shapes

Material: Two wooden cubes of equal dimensions (set A, 2 inches) and two wooden cylinders, also of equal dimensions (set B, 1X3 inches)

Q3 Does this block (indicating one of A) have as much wood in it as that one, or more, or less?

V--How do you know?

Q4 (Indicating one of B) Are these the same, or does this one have more wood or less wood than that one?

V--How do you know?

IIIa The ability to discriminate between amounts in objects of different length (width constant)
IIIb The ability to discriminate between amounts in objects of different width (length constant)

Material: As for level V

IIIa Q5 Is this one (indicating the longer member of set A) longer or shorter or as long as that one (indicating the shorter member)?

Q6 Is it less wide or wider or the same?

Q7 Does it have as much wood as that one, or more, or less?

V--How do you know it has more?

IIIb Q8 (Presenting set B and indicating the narrower cylinder) Is this one wider, or as wide, or less wide than that one?

Q9 Is it as long, or longer, or less long?

Q10 Does it have more wood in it than that one, or less, or the same?

V--How do you know it has less?

IIa The ability to understand the effect of addition on amount
IIb The ability to understand the effect of subtraction on amount

Material: Two plasticine balls which the subject admits are equal (approximately 1½ inches in diameter), and several smaller pieces of plasticine, all of the same color. One cookie (ginger snap).

IIa Q11 (Adding a piece of plasticine to ball A in plain view of the subject) Does this one have the same or more or less plasticine than that one?

V--Why does it have more?

IIb Q12 (Remove the added piece from A until the subject answers that they are still the same when asked Q11. Now remove another piece from A and pose Q11 again.)

V--Why does it have less plasticine now?

IIb Q13 (Removing the balls from the immediate area and presenting the subject with the cookie). Make it have less cookie.

V--How can we make something have less of what it has?

IIa Q14 (Presenting the subject with a plasticine ball) Make this ball have more plasticine.

V--How can we make something have more of what it has?

Ia Combinativity: What has been gained in length has been lost in thickness.

Material: One plasticine ball (1½ inches in diameter)

Q15 (Roll the ball into a short cylinder and hand it to the subject). Make this sausage longer. Is it longer?

Q16 Is it as wide, or wider, or less wide than it was? (thinner?)

Q17 Make it still longer. Now is it wider, or less wide, or just as wide as it was before?

V--What happens to the sausage when it gets longer? Why?

Ib Identity: Nothing has been added or taken away

Material: One plasticine ball ($1\frac{1}{2}$ inches in diameter)

Q18 (Removing plasticine from the ball) Does the ball have as much plasticine as it had before, or more, or less?

V--Why does it have less?

Q19 (Replacing the plasticine on the ball) Does it now have more, or less, or as much plasticine as it had before?

V--Why does it have as much?

Q20 (Rolling the ball around and tossing it from one hand to the other) Does it still have as much plasticine as it had?

V--Why?

Duration of the treatment. Due to the need for recall and re-organization of sub-ordinate capabilities in order to complete the posttest successfully, it was not expected that a very large number of the subjects would be successful on the conservation test after the first training session. This expectation was confirmed in a pilot study. For this reason, three separate training sessions were given to each subject, one day apart, if he had not been successful after the first or second trial. Training sessions lasted approximately ten minutes.

Tests

Conservation of Mass. Test materials consisted of four pairs of identical plasticine balls ($1\frac{1}{2}$" diameter). The subject was asked whether all the balls were the same or whether some had more or less plasticine than others. Plasticine was added or taken away from "unequal" balls until the subject was satisfied that they were all equal.

The standard conservation of substance test usually employs one question or some variation of it: "Is there more plasticine in the ball, or the same amount in both, or more in the sausage (cross, ring, etc.)?" However, this question was not used in this test in order to offset the possibility that the sequential arrangement of "more", "same", and "less" in the question might suggest a desired answer to the student. Instead, subjects were told that the experimenter was going to do something with one of a pair of equal plasticine balls, after which he would say "now". The subject was then to indicate whether the amount of plasticine in the changed ball was the same, more, or less than that in the unchanged ball. In order to ensure that the subject understood the instructions, these were explained until he could repeat them. If the subject was unable to repeat the instructions initially, or if he forgot what was expected of him after the transformation, he was asked specifically whether the transformed ball had more, the same, or less plasticine than the other member of the pair. The sequential order of these adjectives was changed for

each item.

Test items consisted of the following transformations on one member of a pair of balls that had been placed before the subjects:

Test Item	Pair No.	Ball	Transformation
1	1	A	unchanged
		B	a short "sausage"
2	1	A	unchanged
		B	a longer sausage
3	2	A	unchanged
		B	a flat, thick pancake
4	2	A	unchanged
		B	a thinner pancake
5	3	A	unchanged
		B	a cross
6	4	A	unchanged
		B	a circle

Theoretically, subjects who had acquired conservation and who, therefore, answered the first item correctly should also answer all remaining questions correctly and vice versa. As was expected in view of the results of Piaget's experiments (Piaget and Inhelder, 1941), a number of students answered some items correctly but failed one or more. Where this occurred in the pretest, the children were not included in the experimental groups; where it occurred in the posttest or in the retention test, subjects were deemed not to have acquired conservation.

The pretest consisted of items 1, 2, 5, and 6; the posttest, items 3, 4, 5, and 6, and the retention test, items 1, 3, 5, and 6.

Validity. The validity of the three forms of this test is inherent in the definition of conservation of mass. That is, because conservation of mass involves the realization that amount remains invariant despite transformations in shape, an answer to a test item which asks simply whether amount has or has not changed after an object has been reshaped must reflect the present or absence of the notion of invariance. It is, of course, quite possible to train subjects to answer any given item correctly simply by telling them initially what the correct answer is and ensuring through repetition or reinforcement that they will give only that answer when presented with the item--in which case their correct answer would not necessarily reflect a realization of the logical necessity of conservation. In this experiment, however, subjects were not told whether their responses to conservation items were or were not correct. In addition, the validity of the conclusion that children who answered all conservation items correctly had in fact discovered conservation was examined in the light of their ability to transfer the notion of invariance from mass to number. Given that the acquisition of conservation in these two areas occurs at approximately the same place on the ontogenetic scale, and assuming that the sub-ordinate capabilities relating to each are quasi-identical, it is logical to predict that training which leads to the acquisition of one will lead to the acquisition of the other. Data derived from a pilot study undertaken in connection with the present work indicated that number conservation occurred slightly before

conservation of mass. No student answered conservation of mass items correctly without also responding correctly to two conservation of number items, but a few had achieved conservation of number without acquiring conservation of mass. A logical test of the validity of correct conservation of mass responses should then be provided by giving a conservation of number pretest and posttest in conjunction with the conservation of amount pretest and posttest. This was done in the present study. Final results showed that out of 31 subjects who did not have conservation of mass or number prior to training in conservation of mass, 14 responded correctly on both posttests, 3 responded correctly only to the mass items, 1 responded correctly only to the number items, and 13 responded correctly to neither. The high incidence of transfer is added evidence of the validity of the conservation of mass tests.

The conservation of number test (unprovoked correspondence) consisted in rearranging one of two rows of five plastic checker discs of different colors. The first displacement, occurring after the subject had admitted to the numerical equality of the sets, involved lengthening one row. The question asked was, "Are there more red checkers than black ones, or the same number, or not as many." A second displacement, followed by the same question with the alternative responses in reverse order, involved shortening the longer row and lengthening the other.

Reliability. A number of indices of reliability were present in the data. In the first place, under a no-training condition, it

would be expected that a reliable test would yield identical scores for most subjects in a test-retest situation with a not too lengthy time interval. The no-training group in this experiment had scored zero on the pretest. All scored zero on the posttest.

A second index of reliability has to do with the stability of the concept of conservation once it has been acquired. That is, it was expected that subjects who responded correctly on the posttest would also respond correctly on the retention test two weeks later. By the same token, those who responded incorrectly on the posttest should also respond incorrectly on the retention test. Again, this was generally true. Only 1 subject deviated. In this case, the subject scored zero on the retention test after responding correctly to the posttest items (after two training sessions).

Goodenough Draw-a-Man Test. An attempt to get some estimate of the mental ages of the subjects participating in the study involved the use of the well-known Goodenough Draw-a-Man test. Despite the somewhat lower reliability and validity indices of this test as opposed to the more uneconomical Stanford Binet or WISC, it was felt that given the equivocal nature of any measure of intelligence at this age level, the Goodenough test would serve adequately to yield approximate scores that could be used in an attempt to control experimentally what has been postulated as being a factor related to the acquisition of conservation. In addition, these scores were used directly in an attempt to discover whether there was in fact a significant

relationship between mental age and the ability to profit from training in conservation.

A mental age approximation from the Goodenough Test scores was arrived at by interpolation using the Harris tables (Harris, 1963, pp. 294-6). Since the mean score for each age-group in this table is 100, a given raw score was simply assigned the age at which it corresponded to a scale score of 100.

The Canadian Occupational Scale. This scale, constructed by Blishen (1958), was used to arrive at an index corresponding to socio-economic rating (SER). Choice of this scale as opposed to another was dictated largely by the ready availability of information regarding fathers' occupations. The reasons for its inclusion, in the first place, are discussed in the interpretation of results in Chapter V.

Experimental Procedure

Sample. The sample was drawn from the following schools and kindergartens in Edmonton:

	Full conservation on pretest	Pilot study only	Experimental Groups V	NV	NT	Total
Peter Pan Kindergarten	8	5	11	11	11	46
Edmonton Day Nursery		15				15
Grandin School	4		4	4	4	16
St. Anthony's School	5		4	6	5	20
Total	17	20	19	21	20	97

Experimental subjects were selected on the basis of failure to respond correctly to any item on the conservation of mass pretest, and randomly assigned to treatment groups. One way analysis of variance were run in order to ensure that there were no significant differences among the Goodenough Test scores, MA, CA, and SER score means for the treatment groups. This was found to be the case. The Hartley Fmax statistic (Winer, 1962, p. 93) was also computed to examine the assumption of homogeneity of variances for these groups, but is not reported here since none of the tests lead to the rejection of the null hypothesis. Summary data relating to CA, MA, Goodenough test scores, and SER is given in Table I, while the outcomes of the analyses of variance are contained in Table II, A complete tabulation of raw data is found in Appendix A.

Procedure. After the subjects had been administered the conservation of mass and number pretests and the Goodenough test, and assigned to the experimental groups, they were given their respective treatments as outlined previously. At the end of each training session, with both the verbalizing and non-verbalizing subjects, one of the conservation of mass posttest items was selected at random and given to the student. If the subject was successful with this item, the remaining three items were also given and the training discontinued. If he was unsuccessful, the training session was terminated and repeated again on the following day unless this was the third training session--in which case all the conservation of mass items were given regardless

TABLE I

SUMMARY TABLE--MEANS AND VARIANCES INDEPENDENT VARIABLES--ALL GROUPS

Group[a]	V				NV				NT				TOTAL			
Variables[b]	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
5 year-olds	N=11				N=11				N=11				N=33			
Means	83.1	111.5	66.3	69.6	78.2	108.6	65.8	65.4	78.1	108.0	66.2	69.5	79.8	109.4	66.1	68.2
Variances	97.7	92.9	12.02	147.5	141.8	106.9	11.4	135.1	115.9	90.0	9.8	68.7	116.7	92.9	10.4	113.8
6 year-olds	N=8				N=10				N=9				N=27			
Means	85.6	106.4	78.0	52.9	90.5	110.0	77.5	53.7	94.0	113.1	76.0	53.9	90.2	110.0	77.2	53.5
Variances	258.0	185.1	12.9	79.0	89.4	70.0	12.3	163.3	77.2	74.1	13.3	143.9	135.6	104.3	12.5	122.3
Combined Groups	N=19				N=21				N=20				N=60			
Means	84.2	109.3	71.2	65.5	84.0	109.3	71.4	59.8	85.2	110.3	70.6	62.5	84.5	109.6	71.1	61.6
Variances	156.2	130.2	47.1	184.2	150.9	85.4	47.0	176.7	159.5	85.4	35.8	160.6	150.5	96.4	41.9	169.5

a V-verbalizing group NV-non-verbalizing group NT-no-training control

b 1-mental age approximation (MA) 2-Goodenough test standard scores
3-chronological age (CA) 4-Blishen scale ratings (SER)

TABLE II

COMPARISONS BETWEEN TREATMENT GROUPS
ON INDEPENDENT VARIABLE MEANS

Variable[a]		Five year olds	Six year olds	combined age groups
1	F[b]-	0.76	1.11	0.06
	P[c]-	0.48	0.35	0.94
2	F-	0.38	0.92	0.07
	P-	0.68	0.41	0.94
3	F-	0.06	0.74	0.08
	P-	0.94	0.49	0.92
4	F-	0.55	0.02	0,29
	P-	0.58	0.98	0.75

a
1. Mental age approximation (MA)
2. Goodenough test standard scores
3. Chronological age (CA)
4. Blishen scale ratings (SER)

b F--F ratio
c P--The probability associated with obtaining an F ratio of the given magnitude

of success or failure on the first item. Members of the no-training group were given the conservation of mass posttest at approximately the same times as members of the treatment groups and with nearly the same time intervals between pre- and posttest. All subjects were administered the conservation of number posttest (identical to the pretest) immediately after the conservation of mass posttest, regardless of success or failure on that test. Twelve to sixteen days later, all subjects were given the mass retention test and the number test. A record was kept of success or failure on all items of each test and for each question at every level of the treatment hierarchy. In addition, subjects who answered a conservation item correctly were asked to give a reason for the answer on the occasion of their first correct response. A record of the subjects' verbalizations for levels I and III was also kept. Since no subject in the non-verbalizing group attempted to give an overt explanation for his responses, this applied only to the verbalizing group subjects.

The next chapter describes the analyses that were performed on these data in order to arrive at some conclusion regarding the hypotheses in question.

CHAPTER V

ANALYSIS OF DATA

Hypothesis I

The first hypothesis predicted that subjects exposed to a training program based on the sub-ordinate capabilities involved in the development of the notion of conservation of mass would acquire this notion prior to that time when it would have been acquired naturally. A direct test of this hypothesis is provided by a comparison between posttest results obtained by treatment groups and those obtained by the no-training groups.

Because of the fact that only a perfect score of four correct answers was accepted as being evidence of conservation, the criterion data is clearly dichotomous. This, coupled with the invariable incidence of at least one small cell frequency in each contingency table, dictated the use of Fisher's Exact Z, a non-parametric approach (Siegel, 1956).

Separate tests related to the first hypothesis were carried out on posttest results for the V, the NV, and the combined V and NV groups at both the five and six year levels and at combined age levels (Table III). These were repeated for the retention test results (Table IV).

The data clearly support the hypothesis of gains for the experimental groups (V + NV) at the five year level, the six year level, and

TABLE III

POSTTEST RESULTS OF TREATMENT GROUPS (V, NV) COMPARED WITH A CONTROL (NT) USING FISHER'S EXACT Z

AGE LEVEL	VERBALIZING			NON-VERBALIZING			COMBINED		
		-	+		-	+		-	+
5	V	2	9	NV	7	4	V+NV	9	13
	NT	11	0	NT	11	0	NT	11	0
	P <.005			P <.05			P <.01		
		-	+		-	+		-	+
6	V	0	8	NV	6	4	V+NV	6	12
	NT	9	0	NT	9	0	NT	9	0
	P <.005			PNS.			P <.005		
		-	+		-	+		-	+
Combined	V	2	17	NV	13	8	V+NV	15	25
	NT	20	0	NT	20	0	NT	20	0
	P. <.005			P <.005			P <.005		

TABLE IV

RETENTION TEST RESULTS COMPARED WITH
A CONTROL

AGE LEVEL	VERBALIZING			NON-VERBALIZING			COMBINED		
		-	+		-	+		-	+
5	V	2	9	NV	8	3	V+NV	10	12
	NT	11	0	NT	11	0	NT	11	0
		P <.005			NS			P <.005	
		-	+		-	+		-	+
6	V	0	8	NV	6	4	V+NT	6	12
	NT	9	0	NT	9	0	NT	9	0
		P <.005			NS			P <.005	
		-	+		-	+		-	+
Combined	V	2	17	NV	14	7	V+NV	16	24
	NT	20	0	NT	20	0	NT	20	0
		P <.005			P <.05			P <.005	

at combined age levels. In no case is the probability associated with getting a fourfold distribution as extreme as that in question greater than .05. When the data are analysed separately for each of the training conditions, however, only one of the treatments appears to have resulted in consistently significant gains. Whereas the verbalization approach was effective at either age level, the non-verbalization treatment did not produce significant gains on the retention test at either age level, or on the posttest at the six year level. The NV group posttest results at the five year level and both the posttest and retention test results for combined age levels, however, differ significantly from the corresponding NT group results. The evidence, therefore, does not warrant the conclusion that the NV approach is not effective while the V treatment is. That V is superior to NV is shown in the analyses that follow. That NV is effective is made evident by the analysis at combined age levels. It is entirely probable that only the very restricted sample sizes in the NV groups at separate age levels is responsible for the non-significant results obtained there.

Hypothesis II

The second hypothesis predicted simply that those subjects who were made to verbalize their performance of subtasks would be more likely to succeed than those who were not. A test of this hypothesis involved a comparison, using Fisher's exact Z, between V and NV group posttest and retention test results at each age level and for combined

age levels. Outcomes of these tests are given in Tables V and VI. Both posttest and retention test data support the hypothesis at separate and combined age levels. The verbalizing groups were significantly more successful on conservation tests following training than were corresponding non-verbalizing groups. There were no differences between verbalizing and non-verbalizing groups with respect to the number of training sessions required to reach criterion performance. Of those subjects who demonstrated conservation after training, seventy-five percent of the six year olds and fifty per cent of the five year olds were successful after the first session. No subject who was unsuccessful after the second session gave evidence of conservation after the third.

Non Hypothesized Results

While there were no significant deviations from the predicted outcomes of the experiment, at least one postulated relationship and one unstated assumption were not clearly supported by the data.

It will be recalled that the first postulate given in Chapter III stated that there was a positive relationship between mental age and the acquisition of conservation. Mental age approximations derived from the Harris tables (Harris, 1963, pp. 294-6) did not provide unequivocal evidence of this relationship.

In the first place, this postulate would predict that there would be a positive, significant correlation between mental age and

TABLE V

COMPARISONS OF V AND NV POSTTEST RESULTS
USING FISHER'S EXACT Z

5 year-olds

	-	+
V	2	9
NV	7	4

P $< .05$

6 year olds

	-	+
V	0	8
NV	6	4

P $< .025$

5 + 6 year-olds

	-	+
V	2	17
NV	13	8

P $< .05$

TABLE VI

COMPARISONS OF V AND NV RETENTION TEST RESULTS
USING FISHER'S EXACT Z

5 year-olds

	-	+
V	2	9
NV	8	3

P $<.05$

6 year-olds

	-	+
V	0	8
NV	6	4

P $<.025$

5 + 6 year-olds

	-	+
V	2	17
NV	14	7

P $<.05$

success on the pretest. That this was the case was confirmed ($r_{pbi}=.217$; $P < .05$). However, it would also predict that the ability to profit from the treatment is positively related to mental age. The correlation between the posttest and mental age for the treatment groups was, in fact, significant, but negative ($r_{pbi}=-.297$; $P < .05$). It appeared that the children of lower mental age were more successful than were those of higher mental age.

That no single reliable conclusion regarding the relationship of mental age to the acquisition of conservation can be reached is inherent in the contradictory nature of these results. Two separate and improbable conclusions could be advanced; mental age is positively related to the natural development of conservation, but negatively related to its artificial development. No conclusions of this nature are intended here, however, given that none of these correlation coefficients are significant at the .01 level, and that the MA scores are admittedly only approximations (see p. 40). In addition, the restricted range of these scores necessarily militates against the observation of a relationship which might still hold, as postulated, over a wider range.

The unstated assumption not supported by experimental results is that the six year-olds would be more successful than the five year-olds, despite the fact that the acquisition of conservation was postulated as being relatively independent of age level. This may be

true for individual cases notwithstanding that, in general, older subjects would be expected to acquire conservation in greater numbers that younger students. In this case, however, 8 out of 46 five year-olds had conservation previously whereas 9 out of 36 six year-olds were successful on the pretest. The difference between these proportions is not significant although it is in the right direction. Success on the posttest, however, is even less indicative of a difference in favor of the six year-olds. Where 12 out of 18 six-year olds were successful, 13 out of 22 five year-olds responded correctly.

In an attempt to explain these two contradictions of assumed and postulated relationships, a third hypothesis was formulated and tested. It was expected that one of the groups would be atypical in terms of some independent variable bearing a higher degree of relationship to the criterion than either chronological or mental age within this rather restricted range. An index of socio-economic level (SER) given by the Canadian Occupational Scale prepared by Blishen (1958) was employed in an attempt to define this variable. The hypothesis predicted that the five year-old sample would have higher socio-economic ratings than the six year-olds, and that the correlation between success or failure on conservation tasks and the Blishen Scale ratings would be both significant and positive.

A simple comparison of mean SER scores for five and six year-olds using analysis of variance did, in fact, indicate that the

samples were significantly different. The five year-old sample had a higher mean SER than did the six year-olds ($F = 27.03$; $P < .0001$). In addition, the relationship between this rating and ability to profit from training, as evidenced by the correlation between posttest scores and SER was both positive and significant ($r_{pbi} = .277$; $P < .05$).

Indications are, then, that SER may be a better predictor of success on conservation tasks than is MA. Although the relationship is not significant beyond the .01 level, and although relatively small samples were involved, the fact that the five year-old SER mean was higher than the corresponding mean for the six year-olds, and that, contrary to expectation, they performed as well on conservation tasks, adds further support to this conclusion.

Summary of Analysis

Fisher's Exact Z, a non parametric test, was employed to examine the tenability of the hypotheses at the core of this study. Results of the analyses support both hypotheses. Analysis of the Canadian Occupational Scale ratings indicated that socio-economic status was, for this chronological and mental age range, a more important variable than either mental or chronological age in terms of degree of relationship to the acquisition of conservation.

The following chapter discusses the development and validation of the treatment hierarchy.

CHAPTER VI

THE TREATMENT HIERARCHY

Development of the Hierarchy

The treatment hierarchy presented in Chapter IV was developed in the light of the following practical and theoretical requirements:

1. Each level in the hierarchy must be logically subordinate to the next highest level.

2. Progression through the hierarchy from the lowest to the highest level should lead logically to the development of the notion of invariance.

While it is simple enough to evaluate the treatment hierarchy in terms of experimental results, the initial development of the scale must necessarily precede experimental evaluation of that scale. In this case, however, previous research on the development of conservation, as well as Piaget's developmental model, indicated at least one starting point. It has been found that children justify correct conservation of mass responses in typically similar ways--they argue that nothing has been added or removed, that while a transformed object appears larger in one dimension it is smaller in the corresponding dimension, or that there was the same amount before and must therefore still be the same amount. These arguments are examples of what Piaget labels the operations of identity, combinativity and reversibility (Piaget and Inhelder, 1941)--operations which result from the quantification of the properties of an object which, in turn, is preceeded by the

realization of the permanence or identity of objects. Following this Piagetian descriptive model, identity, reversibility, and combinativity were placed at the top level of the hierarchy. An attempt was then made to develop a scale comprising abilities implied by the top level until level VI had been reached. This level, defined as the comprehension of the meanings of "more", "the same", and "less than" in relation to amount of substance, was later deleted partly for the same reason as the scale was discontinued at this point--the reason being that, although it is probably at least theoretically possible to continue delineating sub-ordinate capabilities from the notion of invariance, through the development of the notion of the permanence of objects, until the first primary reflex is reached, no treatment program of this nature can justifiably be inefficient enough to go beyond that level where most subjects have a reasonably high probability of success.

It is important to note that the hierarchical classification of abilities developed for this experiment is only one of many possible combinations. The degree of success obtained by use of the treatment based on this hierarchy is not to be construed as evidence that all levels of the scale are essential; that the scale is complete, or that the questions corresponding to each level of the scale are the best of many alternative questions. On the other hand, that there is something in the treatment hierarchy which is in some way related to the development of conservation is evidenced by the fact that experimental

groups outperformed no-training groups. Whether this "something" is the hierarchy itself, or whether the materials alone, or simply interaction with the examiner could have produced similar changes in the treatment groups cannot be readily determined from this experiment. However, the contention that neither of these factors without the hierarchical treatment employed could have produced these results would seem to be supported by the lack of success obtained by previous investigators, where, regardless of the treatment used, there was usually sufficient opportunity to manipulate materials and to interact with the examiner.

Validation

The hierarchy of sub-ordinate capabilities presented earlier is in part the result of a pilot study which was conducted prior to the experiment central to this work. This study was designed primarily to assess the total effectiveness of the treatment hierarchy, and secondly, to examine the accuracy of the linear arrangement of subordinate capabilities. Twenty subjects comprised the pilot study sample. Five of these subjects were between five and six years of age. They were given complete training sessions identical to those reported in this study. The remaining fifteen subjects were aged between four and five with an average age of approximately 4-6. These subjects were simply given the treatment hierarchy with a view to determining whether or not the capabilities proper to each level were

in the correct order.

Two changes in the original hierarchy were indicated by the results of this preliminary study. These involved the deletion of the bottom level of the hierarchy, and the deletion of a third capability at level I. The bottom level (level VI) had been defined as the ability to understand the meanings of "more", "the same", and "less" in relation to amount of substance. A tabulation of responses to each item for fifteen subjects indicated that level VI was probably misplaced or not essential. While none of the subjects responded correctly at VI without also responding correctly at V and IV, in several instances where level VI was failed, both of the next two levels were still correct. Since one of the basic requirements to be satisfied in constructing a hierarchy of this nature is that no one should succeed at any level beyond that where he first failed, simply changing the order of this item by placing it above level IV might have been sufficient--that is, this would have corrected the rank order of these three levels. A closer examination of levels IV and III, however, revealed that correct responses to these levels implied the abilities formerly defined in level VI. Moreover, none of the five year old subjects failed level VI in the pilot study. There did not appear to be any reason, then, to include level VI as part of the treatment for the study proper since the groups involved did not include any subjects younger than five.

The second deletion indicated by the pilot study involved a third capability at level I (Ic) which had been defined as simple reversibility, or the ability to return to the starting point. While all the other levels now appeared to form a reliable ordinal scale, this ability did not clearly belong at any given position in the hierarchy. All but two subjects were successful at level Ic regardless of prior successes or failures.

The decision to remove Ic from the hierarchy was based on three considerations: first, it did not appear to belong in the ordinal arrangement of capabilities; secondly, it had not been used as a justification for correct conservation responses by any subject, and thirdly, the type of operational reversibility inherent in the notion of conservation seems to involve more than simple awareness that it is possible to return to the starting point. This latter point is made clear by Piaget and Inhelder (1941):

> ...le simple retour empirique au point de départ ne suffit point à assurer la conservation parce qu'il ne constitue point encore une réversibilité vrai. (p.17)

The advent of true reversibility is defined in terms of the discovery of the inverse operation on a mental rather than an empirical plane ("la découverte de l'opération inverse en tant qu'opération" (Piaget and Inhelder, 1941, p. 17)). But more important than operational reversibility as a precursor of conservation is what Piaget calls <u>identité</u>, and by this he means exactly the capability which has

been labelled identity in the hierarchy (level Ib)--more important because the fact that nothing has been added or taken away from a transformed object is used as a justification for a correct conservation response more often than is reversibility per se (the notion that if one were to retransform the object it would be identical to the object that it was before). In this study, 12 subjects who responded correctly to conservation items prior to training used identity as a justification, 2 invoked simple reversibility, and 3 employed combinativity. After training the numbers were 13, 2, and 8 respectively, with 2 non classifiable.

Two things are of note here. First, identity does, in fact, involve reversibility. That the child realizes the effects of addition or subtraction implies that he is able to compare the attributes of the deformed object to its attributes prior to deformation. Secondly, combinativity (level Ia), mentioned by Piaget and Inhelder as a less frequent justification for conservation (1941, p. 28), also involves reversibility in the same sense that identity does. It appears reasonable to argue that a child notices compensation of changes in dimensionality only when he becomes aware of these changes by comparing a transformed object to its original form--a comparison which implies operational reversibility. The removal of level Ic (simple reversibility) does not, therefore, imply the removal of the operation of true reversibility as a sub-ordinate capability in the hierarchy.

Scale Reliability

Thus far, this chapter has presented certain criteria that were employed in the development of the hierarchy and an attempt to evaluate the logical plausibility of the sub-ordinate capabilities included in it. Experimental results attest to the effectiveness of the scale in terms of the purpose for which it was constructed, but cannot establish its superiority over other possible scales. The reliability of the scale itself, in terms of its linear order, was examined using scalogram analysis, an approach developed by Guttman (reported in Torgerson, 1958).

The concept of scale reliability is analogous to its reproducibility--a property defined in terms of the accuracy with which an individual's position on the scale predicts all of his responses. For any one scale there are a given number of perfect scale types. For example, where the scale levels are ordered from easiest to most difficult, perfect scale types are represented by those people who pass all items, fail all items, or pass a number of easy items but fail all of the remainder. The unreliability of the ordering of scale items is then reflected by the number of deviations from perfect response patterns. A coefficient of reproducibility is yielded by the formula (Torgerson, 1958, p. 319):

$$\text{Rep} = 1 - \frac{\text{total number of errors}}{\text{total number of responses}}$$

Any coefficient above .90 is felt to indicate sufficient scale reliability.

In order to examine the scale properties of the hierarchical treatment employed in this study, it was necessary to determine what passing or failing a level involved. An examination of the questions used for the treatment shows that the last question for each level is the crucial one, and could therefore be used as the criterion for passing or failing that level. The performance of all subjects who were administered the hierarchy, including the pilot study sample, is shown in Table VII. It is obvious from this table that the rank order of levels is correct and that the coefficient of reproducibility would be well above .90. However, this coefficient is relatively meaningless in view of the fact that two assumptions have not been met--there are fewer than 100 subjects, and fewer than 10 levels. Nevertheless, the very high incidence of perfect scale types, coupled with a correspondingly low incidence of errors, attests to the scale properties of the hierarchy.

TABLE VII

PATTERN OF RESPONSES TO THE LAST ITEM
AT EACH LEVEL OF THE HIERARCHY

Frequency	Va	Vb	IV	IIIa	IIIb	IIa	IIb	Ia	Ib
Perfect Scale types									
30	+	+	+	+	+	+	+	+	+
4	+	+	+	+	+	+	+	+	-
2	+	+	+	+	+	+	+	-	-
1	+	+	+	+	+	+	-	-	-
5	+	+	+	+	+	-	-	-	-
2	+	+	+	+	-	-	-	-	-
5	+	+	+	-	-	-	-	-	-
1	+	+	-	-	-	-	-	-	-
1	+	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-
Errors									
1	-	-	+	-	-	-	-	-	-
1	+	+	+	+	+	+	+	-	+
1	+	+	+	-	-	+	+	+	+
1	+	+	+	+	+	-	-	+	-
60	54	53	53	46	44	39	38	36	32

[illegible]

CHAPTER VII

SUMMARY, INTERPRETATION, AND IMPLICATIONS

Summary of Experimental Findings

Two hypotheses were examined in this study. The first predicted that a training program based on the capabilities presumed to be necessary for the acquisition of the notion of invariance would lead to the development of that notion in experimental subjects. The second predicted that these subjects who were asked to verbalize their performance of subtasks would be more likely to succeed on the final conservation tests.

These hypotheses were examined in terms of the results of a controlled experiment--controlled in the sense that the respective experimental groups after random assignment of subjects to groups, were examined on a number of factors of significance in ontogenetic development. The three experimental groups were found to be matched by means and variances with respect to Goodenough Test scores, MA, CA, and SER. One group was trained using verbalization (V), one was trained without (NV), and one served as a no-training control.

A test of the first hypothesis involved a comparison of V with NT, NV with NT, and combined V and NV with NT groups. It was concluded that the data support the hypothesis despite non-significant results with the NV groups at separate age levels. The indication is that the small sample sizes coupled with the relatively less

powerful non-parametric tests employed serve to explain lack of significance here. At any rate, the experimental groups, both verbal and non verbal, when considered _in toto_ over both age levels, showed significant gains relative to the no-training groups. No conclusion was reached regarding the relative effectiveness of the treatment for five and six year-olds respectively in view of the atypicality of the five year-olds in terms of socio-economic rating (SER). That they performed as well as their six year-old counterparts is probably a function of this higher SER.

A test of the second hypothesis involved a comparison between V and NV groups at separate and combined age levels. Unlike the tests carried out relative to the first hypothesis, in this case significant results were obtained at both age levels. Verbalization was clearly a significant factor in the acquisition of conservation through training. Retention test results were identical to posttest results for all but one subject. In addition, there was a high incidence of transfer from mass to number items (see page 39).

Interpretation and Implications

Given the fact that the results of the experiment were mainly as hypothesized, any detailed interpretation of these outcomes would entail little more than a recapitulation of the theoretical postulates from which the predictions were derived. The results which are most noteworthy are the obvious ones: conservation of mass can be induced

in subjects, and verbalization is a significant factor in its development. Some of the questions arising from the study which are noteworthy are also obvious ones: (1) how can the training hierarchy be improved? (2) what are the limitations of an attempt to accelerate ontogenetic development in this area? The conclusions are dealt with in the first part of this chapter--the questions and their implications for further research are dealt with below.

(1) How can the training hierarchy be improved?

In the previous chapter an account is given of the development and validation of the hierarchy of sub-ordinate capabilities. Attention is drawn to the fact that the validity of the rank order of capabilities does not imply the logical necessity of each level of the hierarchy with respect to the development of conservation. Nor can the demonstrated effectiveness of the treatment as a whole be employed to justify the inclusion of any particular level, or of any specific capability within a level. While the Piagetian descriptive model of the development of conservation serves as a theoretical justification for this hierarchy, it does not dictate the inclusion of each of the five levels, but rather indicates only the general nature of the composition of the scale.

A different scale could have been developed using another theoretical approach. For example, an extension of the Brunerian model for the development of ways of representing the environment (Bruner, 1964) would lead to the formation of a scale reflecting enactive,

iconic, and symbolic processes at successive levels. The content of the hierarchy, in terms of the capabilities themselves, could be nearly identical to that developed for this study, but the questions proper to each level would progress systematically from the enactive type, where the subject would be asked to perform actions with objects, to the iconic type, where he would be presented concrete evidence of transformations, and finally to the symbolic type where a screen might be placed between the objects and the child so that the interaction would be largely verbal.

The implication here is that any improvement of this scale or the development of a better scale would result from a closer examination of the theoretical position on which the scale is based, or from the incorporation of other theoretical positions in the construction of the scale. In addition, the means that were used to develop the capabilities defined at each level are only one of several alternatives. Perhaps repetition with more varied materials, a didactic as well as a discovery approach, group rather than individual training, or a combination of these would prove more effective and/or more efficient. The effectiveness of a training program in terms of the stability and permanence of the changes effected by it could be examined more carefully by employing some variation of the Smedslund extinction experiment (1961c). For example, while the equality or inequality of weights can be ascertained more readily than that of masses, it might be possible to obtain an effect similar

to that obtained by Smedslund simply by suggesting inequality to the subject.

(2) What are the limitations of an attempt to accelerate ontogenetic development in this area?

There is little in the literature relating to development which gives any clear evidence of the limitations that exist for any attempt to develop conservation in young subjects. While the contention that "maturational considerations inevitably impose a limit on such acceleration" (Ausubel in Aschner and Bish, 1965, p. 56) is necessarily true given the inclusive connotations of the term maturation, it has not been demonstrated that at least some aspects of maturation cannot themselves be accelerated. Indeed, if the development of conservation is accepted as being one manifestation of intellectual maturation, then obviously maturation is not an insurmountable barrier to induced development. On the other hand, if the term maturation is limited to its connotations of physical and neurological growth, no conclusive statement can be made regarding the extent to which it imposes a limit to an attempt to accelerate development.

In the same way, the contention that the transition between stages presupposes "the attainment of a critical threshold level of capacity reflective of extended and cumulative experience which can only be reduced up to a point" (Ausubel, 1965, p. 56) has not been subjected to rigorous examination. Where attempts to affect the development of the notion of invariance have been limited to the development

of those capabilities which correspond to the top level of the hierarchy presented in this study, as was the case in the Smedslund studies reported earlier, failure to develop conservation may be explained in terms of the non-attainment of the critical threshold mentioned by Ausubel. On the other hand, the present study gives some indication that it may be possible to develop the capacities which define this critical threshold. It has been argued by Piaget and Inhelder (1941) that the development of the notion of conservation signals the completion of objectification regarding physical objects and the beginning of the ability to differentiate and to quantify attributes. A training program designed to develop conservation, but based solely on the development of high-level operations (identity or combinativity) presupposes both the presence of a fully developed notion of object identity and permanence on the part of the child, and an awareness of the qualitative and quantitative characteristics of object attributes--and is necessarily very likely to be unsuccessful in the absence of these. On the other hand, a training program of this nature geared not only towards the development of these operations, but first towards the development of supportive conceptual frameworks (the ability to quantify attributes) should be more likely to succeed in the absence of the capabilities proper to the critical threshold. That Wallach and Sprott (1964) were successful in inducing number conservation without recourse to anything but an attempt to develop reversibility in children who did not previously have

conservation may be explained by the fact that the mean age of those children was 7 years. It is likely that they already possessed most of the sub-ordinate capabilities necessary for the acquisition of conservation.

The important implication here is a general one--that is, it is one which can be applied to the acceleration of the development of concepts other than that of conservation of mass. It is simply that any successful attempt to develop high-level abilities in children must either presuppose the presence of relevant sub-ordinate capabilities, or, in the absence of these, must make provision for their development.

Further Implications

The implications derived from the study thus far have dealt with suggestions for improving the treatment hierarchy and with the role of an analysis of relevant sub-ordinate capabilities in acquisition experiments. The importance of this type of research can be appreciated more fully when viewed in the context of the total ontogenetic growth of the child.

Admittedly, the realization that amount remains invariant despite deformations does not appear to be a very important developmental phenomenon *per se*. However, a correct conservation response implies more than a simple awareness of invariance; it marks the end of the period of intuitive reasoning even as it signals the beginning of the concrete level of operations; but, more important, it is the

first evidence of the co-ordinated use of the operations of identity, reversibility, and combinativity--operations which, together with associativity and tautology or iteration, not only define concrete reasoning, but also serve as the essential elements from which the child's intellectual structure will be constructed. Whether these operations are ordinarily the causes of the development of conservation, or whether they, in fact, result from the realization of invariance, they may still be viewed as the *sine qua non* of future intellectual development. For this reason, it can be argued that an attempt to develop the concept of conservation in a child is, in effect, an attempt to develop his intellectual potential, or, at least, to ensure that a significant aspect of his development is not neglected. Furthermore, logical extrapolation of the success obtained in this study would indicate that it may well be possible to accelerate development at any other level in the ontogenetic scale. If this is, in fact, the case (and considerable research is needed before it can be asserted), it may be extremely worthwhile to undertake the development of an inclusive hierarchical model of intellectual growth, appropriate portions of which could then be used with all types of children, from the mentally retarded to the most gifted.

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A P P E N D I X

APPENDIX A

SYMBOLS AND CODE

Variable	Identification	Code
A	Identification number	
B	Mental age approximation (months)	
C	Goodenough Test Scores (Harris Tables)	
D	Chronological age (months)	
E	Blishen Scale ratings	
F	Conservation of Mass--Pretest	1--pass 0--fail
G	Conservation of Mass--Posttest	1--pass 0--fail
H	Conservation of Mass--Retention test	1--pass 0--fail
I	Conservation of Number--Pretest	1--pass 0--fail
J	Conservation of Number--Posttest	1--pass 0--fail
K	Conservation of Number--Retention test	1--pass 0--fail
L	Treatment Group of Subject	1--verbalizing 2--non-verbalizing 3--no-training control 4--full conservation on pretest
M	Age group of subject	5--five year-old 6--six year-old
N	Number of training sessions	

[illegible]

APPENDIX A

SUMMARY TABLE OF RAW DATA

					Variables								
					Mass			Number					
A	B	C	D	E	F	G	H	I	J	K	L	M	N
01	090	116	61	72	0	1	1	0	1	1	1	5	2
02	078	107	70	63	0	1	1	1	1	1	1	5	1
03	072	104	61	83	0	1	1	0	1	1	1	5	1
04	088	113	66	78	0	1	1	0	1	1	1	5	1
05	091	122	71	72	0	1	1	0	0	0	1	5	2
06	090	119	67	68	0	0	0	0	0	0	1	5	3
07	086	116	66	81	0	1	1	0	1	1	1	5	1
08	059	087	66	62	0	1	1	0	1	1	1	5	2
09	086	116	63	81	0	1	1	1	1	1	1	5	2
10	090	116	68	41	0	0	0	0	0	0	1	5	3
11	084	110	70	64	0	1	1	1	1	1	1	5	1
12	091	122	63	81	0	0	0	0	0	0	2	5	3
13	066	099	62	79	0	1	1	0	1	1	2	5	1
14	092	119	69	62	0	0	0	0	0	0	2	5	3
15	091	122	63	64	0	0	0	0	1	0	2	5	3
16	062	093	66	60	0	0	0	0	0	0	2	5	3
17	092	119	68	62	0	0	0	0	0	0	2	5	3
18	078	107	69	83	0	1	1	1	1	1	2	5	1
19	066	101	62	62	0	1	0	0	1	0	2	5	2
20	066	099	71	50	0	1	1	0	1	1	2	5	2
21	078	107	70	48	0	0	0	0	0	0	2	5	3
22	078	107	67	68	0	0	0	0	0	0	2	5	3
23	083	113	65	81	0	0	0	0	0	0	3	5	0
24	076	105	61	64	0	0	0	0	0	0	3	5	0
25	078	107	66	62	0	0	0	0	0	0	3	5	0
26	090	119	70	62	0	0	0	1	1	1	3	5	0
27	062	093	71	79	0	0	0	0	0	0	3	5	0
28	063	095	64	57	0	0	0	1	1	1	3	5	0
29	090	119	64	72	0	0	0	0	0	0	3	5	0
30	072	104	67	72	0	0	0	0	0	0	3	5	0
31	072	104	69	65	0	0	0	0	0	0	3	5	0
32	095	122	63	70	0	0	0	0	0	0	3	5	0
33	079	107	69	81	0	0	0	0	0	0	3	5	0
34	063	095	66	68	1			1			4	5	
35	078	107	68	72	1			1			4	5	
36	099	128	70	58	1			1			4	5	
37	076	105	64	68	1			1			4	5	
38	078	107	65	60	1			1			4	5	
39	122	150	70	81	1			1			4	5	
40	066	101	68	81	1			1			4	5	

APPENDIX A (continued)

41	078	107	65	81	1			1			4	5	
42	090	110	81	62	1			1			4	6	
43	078	099	75	75	1			1			4	6	
44	096	115	74	41	1			1			4	6	
45	102	118	76	42	1			1			4	6	
46	127	150	80	56	1			1			4	6	
47	090	110	83	48	1			1			4	6	
48	114	130	75	62	1			1			4	6	
49	102	120	81	65	1			1			4	6	
50	102	120	80	48	1			1			4	6	
51	114	133	73	50	0	1	1	1	1	1	1	6	1
52	078	099	77	48	0	1	1	0	0	1	1	6	1
53	091	112	83	44	0	1	1	1	1	1	1	6	1
54	083	104	76	49	0	1	1	0	1	1	1	6	1
55	100	115	81	72	0	1	1	0	1	1	1	6	2
56	072	096	81	47	0	1	1	0	1	1	1	6	1
57	084	103	74	56	0	1	1	0	1	1	1	6	2
58	063	089	79	67	0	1	1	1	1	1	1	6	1
59	078	100	82	49	0	0	0	1	1	1	3	6	0
60	102	118	77	49	0	0	0	0	0	0	3	6	0
61	088	105	77	44	0	0	0	0	0	0	3	6	0
62	091	112	79	52	0	0	0	0	0	0	3	6	0
63	105	123	72	46	0	0	0	0	0	0	3	6	0
64	100	115	73	64	0	0	0	0	0	0	3	6	0
65	090	108	79	56	0	0	0	0	0	0	3	6	0
66	102	127	72	81	0	0	0	0	0	0	3	6	0
67	090	110	73	44	0	0	0	0	0	0	3	6	0
68	090	108	73	56	0	1	1	1	1	1	2	6	2
69	078	100	73	62	0	1	1	0	1	1	2	6	1
70	092	110	82	42	0	0	0	0	0	0	2	6	3
71	092	110	77	46	0	1	1	0	1	1	2	6	1
72	096	115	77	64	0	0	0	0	0	0	2	6	3
73	083	104	74	47	0	0	0	0	0	0	2	6	3
74	095	114	83	56	0	0	0	0	0	0	2	6	3
75	078	099	78	81	0	1	1	0	0	1	2	6	1
76	110	128	80	41	0	0	0	0	0	0	2	6	3
77	091	112	78	42	0	0	0	0	0	0	2	6	3